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DOCUMENTATION FOR SNSIM1/2, A COMPUTER PROGRAM FOR THE STEADY-STATE WATER QUALITY SIMULATION OF STREAM NETWORK

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Documentation for

SNSIM1/2

"A computer program for the steady-state water quality simulation of a stream network

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ACKNOWLEDGEMENTS

INTRODUCTION

The concentration of dissolved oxygen (DO), carbonaceous biochemical oxygen demand (CBOD) and nitrogenous biochemical oxygen demand (NBOD) are some of the most significant criteria in determining the extent of the present or possible future degradation of water quality due to the discharge of biodegradable wastewater into a natural water system. Using systems analysis, a mathematical model can easily be written to determine the levels of DO, CBOD, and NBOD in a stream.

SNSIM is a computer program which can be used to formulate a steady-state, one dimensional, simulation model of a stream network. It is designed to evaluate and/or predict the dissolved oxygen, and the carbonaceous and nitrogenous BOD profiles in a river or stream where the effects of dispersion can be assumed to be insignificant.

The stream network consists of a river and its tributaries which are segmented into sections of constant hydrologic, physical, chemical and biological parameters. Loads may be applied pointwise at the ends of the section or as distributed sources along its length. A summary of the loads is given below:

BOD Loads

Point loads-carbonaceous and/or nitrogenous

(e.g., an industrial waste)

Distributed loads-carbonaceous and/or nitrogenous

(e.g., agricultural runoff)

D.O. Deficit Loads

Distributed Loads - Benthal Demand

- Photosynthetic Demand

As well, point sources of both BOD and DO deficit from minor tributaries can be input at the ends of a section and background loads of BOD and DO deficit can be introduced at the system's upstream ends.

An analytical expression is then applied to each section to determine their CBOD, NBOD and DO deficit response to the loadings. This expression is similar in form to the classic Streeter-Phelps equation. Mass balances are applied at the junction of sections as well as the more complex junction of the systems tributaries. In this way the program generates results for the entire system.

This documentation consists of a description of the program as well as its input. A listing of both versions of the program (SNSIM1 being compatible with the IBM 370/155 while SNSIM2 is compatible with the IBM 1130) and an example problem are included in the appendices.

The System: Definition of Terms

- A REACH is that part of a stream from its source (furthest upstream point of interest) or confluence to the next confluence. Figure 1 shows a hypothetical river network. As can be seen the branches of the river are numbered and each is referred to as a "reach".

- A CONFLUENCE is the point at which two or more reaches join. At present, SNSIM allows up to 4 reaches to be joined at a confluence.

- A SECTION is that part of a reach which can be described by constant physical, chemical, hydrological and biological characteristics. An example of sectioning is shown in the example problem (Appendix B). Each section in a reach may have a waste source and/or minor tributary at each of its boundaries.

- A MINOR TRIBUTARY is one which is not to be described by the model but only serves as an input to the system. "Silverload Run" from the example problem in Appendix B is a minor tributary.

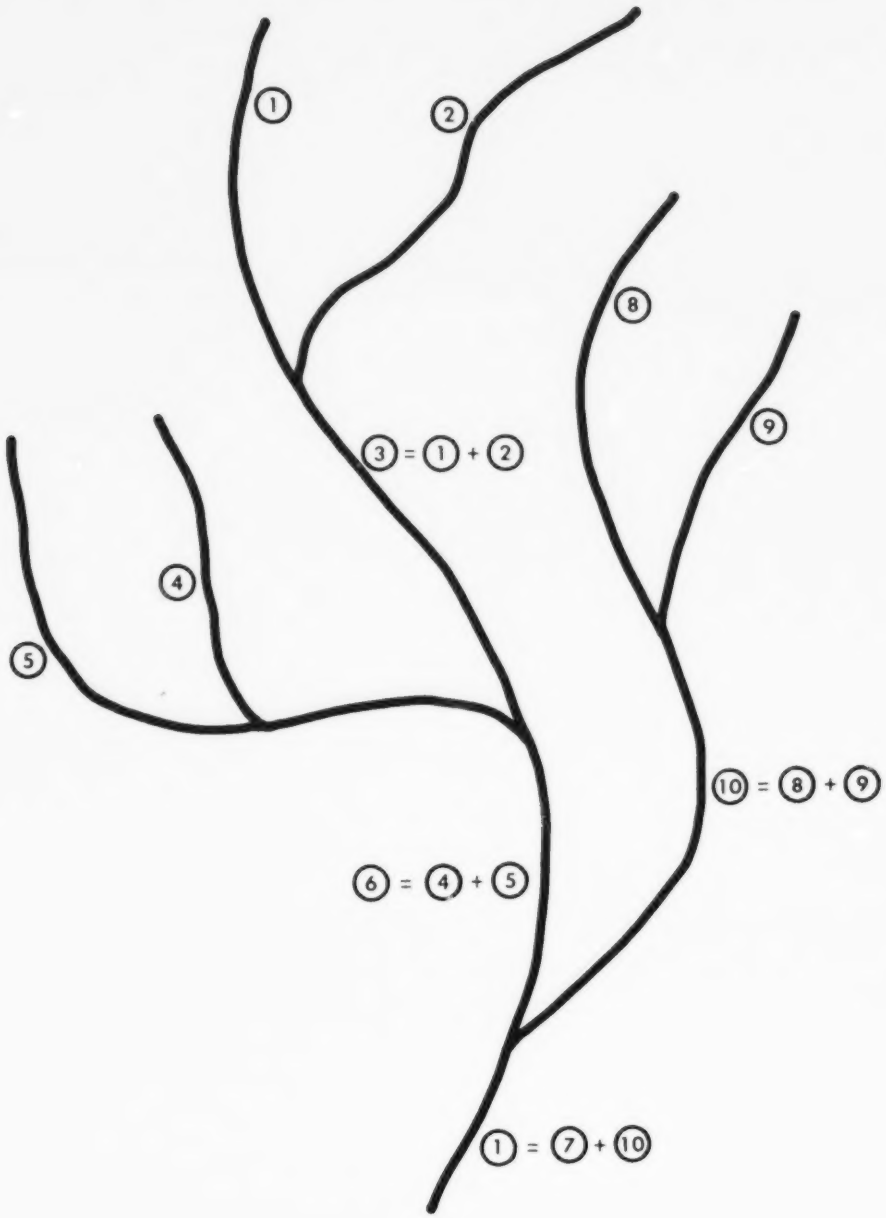


FIGURE 1

Theory

The equations for the calculation of the distribution of CBOD, NBOD and DO deficit in a Section are as follows:[1]

$$CBOD = CBOD_o \exp[-(K_r/u)x] + (CBOD_d/Kr)(1-\exp[-(K_r/u)x])^* \quad \ldots\ldots (1)$$

$$NBOD = NBOD_o \exp[-(K_n/u)x] + (NBOD_d/K_n)(1-\exp[-(K_n/u)x]) \quad \ldots\ldots (2)$$

$$D = D_o \exp[-(Ka/u)x] \quad \ldots\ldots (3a)$$

$$+ \frac{Kd}{Ka-Kr}(\exp[-(Kr/u)x]-\exp[-(Ka/u)x])CBOD_o \quad \ldots\ldots (3b)$$

$$+ \frac{Kn}{Ka-Kn}(\exp[-(Kn/u)x]-\exp[-(Ka/u)x])NBOD_o \quad \ldots\ldots (3c)$$

$$+ \frac{Kd}{KaKr}(1-\exp[-(Ka/u)x])CBOD_d$$

$$- \frac{Kd}{(Ka-Kr)Kr}(\exp[-(Kr/u)x]-\exp[-(Ka/u)x])CBOD_d \quad \ldots\ldots (3d)$$

$$+ \frac{1}{Ka}(1-\exp[-(Ka/u)x])NBOD_d$$

$$-\frac{1}{(Ka-Kn)}(\exp[-(Kn/u)x]-\exp[-(Ka/u)x])NBOD_d \quad \ldots\ldots (3e)$$

$$-(1-\exp[-(Ka/u)x])\frac{P}{Ka} \quad \ldots\ldots (3f)$$

$$+(1-\exp[-(Ka/u)x])\frac{R}{Ka} \quad \ldots\ldots (3g)$$

$$+(1-\exp[-(Ka/u)x])\frac{Sb}{Ka} \quad \ldots\ldots (3h)$$

*$\exp[y] = e^y$

where the elements of the deficit equation are interpreted as follows:

(3a) point source* of DO deficit and initial value of DO deficit

(3b) deficit due to point source* of CBOD

(3c) deficit due to point source* of NBOD

(3d) distributed source of CBOD deficit input with no significant addition to river flow

(3e) distributed source of NBOD deficit input with no significant addition to river flow.

(3f) deficit due to distributed gross photosynthesis

(3g) distributed algal respiration effect

(3h) distributed benthal demand effect

Definitions of the various terms in the equations can be found in the nomenclature (page15). For a concise discussion of these equations and stream modelling in general see Thomann.[1]

* Point source in the equation refers to all input which occurs at the upstream end of the section to which the equation applies. This may include effluent point loads, minor tributary loads, and all input from the downstream ends of the sections directly upstream from the section in question. In other words, the total point source is the boundary condition at the upstream end of the section.

The Computer Program*

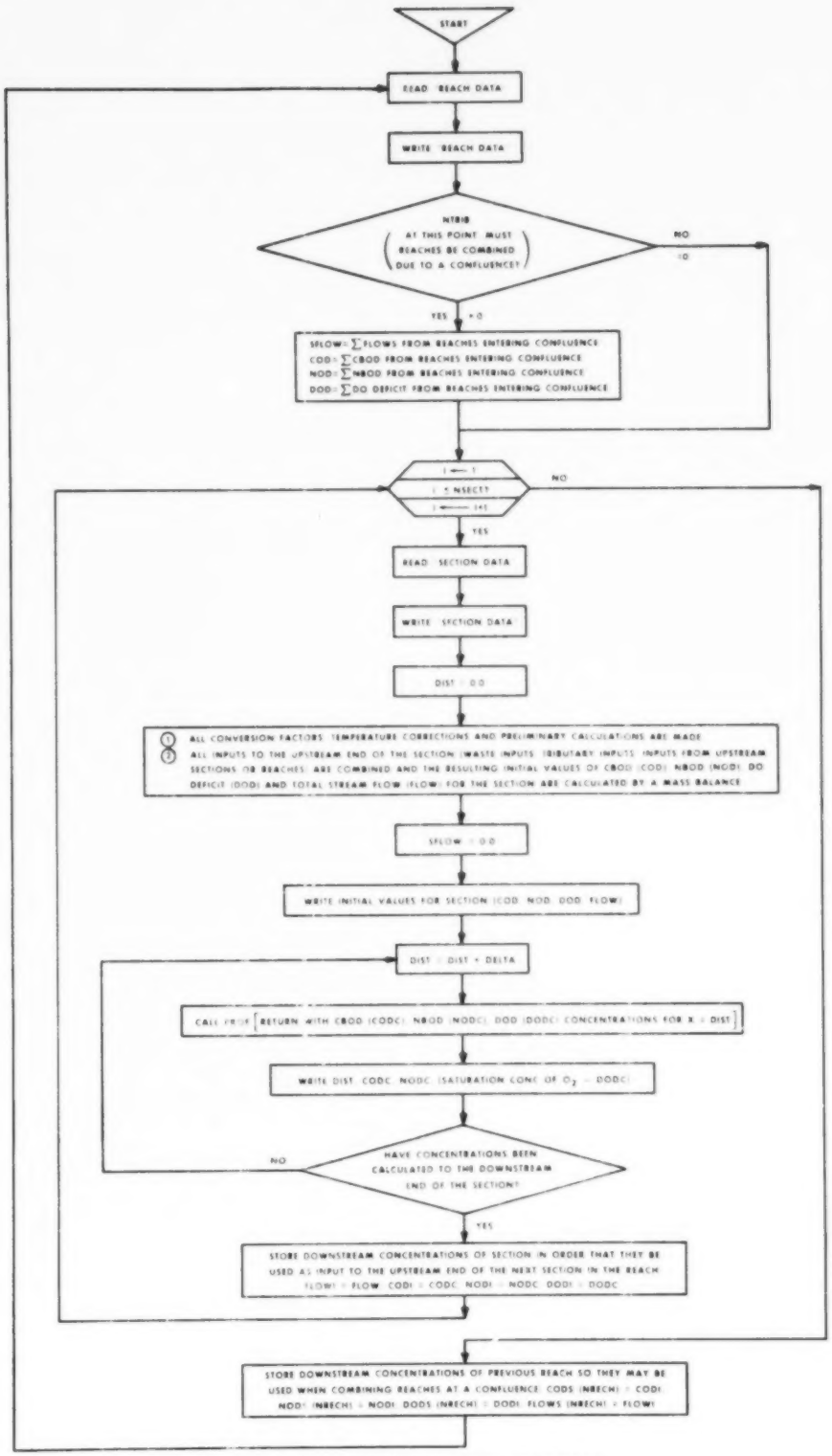
The program begins by reading and writing the name of the river (TITLE). Then the general data for the initial stream conditions upstream of the first section are read. These are the instream flow (FLOWI), the instream carbonaceous demand (CODI), instream nitrogenous demand (NODI), instream dissolved oxygen deficit (DODI), the increment size for a section output (DELTA), an integer (NDIST) representing the reach number of the starting milepoint, the number of sections in the reach (NSECT), the reach number (NRECH), the number of tributaries or reaches to be combined (NTRIB), and the reach numbers (NT(I), I=1,2,3,4) which are to be combined.

SNSIM is capable of stream network simulation. Each reach must be assigned a reach integer (NRECH) between 1 and 10. At a confluence of two reaches, three reach numbers will be required--one for each of the 2 reaches before the confluence, and 1 to represent the reach after confluence. In this program, only the data for the combined effects will be required to continue computations for the stream network. It is only necessary to use the 3rd reach number for further computations, once the program has read in data for the confluence. The two reach numbers representing reaches before the confluence may be reassigned elsewhere in the stream network.

In Figure 1, Reach 1 is the uppermost reach, and includes all river sections from the source to the confluence with Reach 2. The data for Reach 3 represents the combined effects of 1 and 2, so that Reach numbers 1 and 2, may now be used to represent other reaches. In this diagram, consecutive reach numbers are used (up to 10) and at the confluence of Reaches 7 and 10 "1" is used again. At this point any of the other reach numbers (besides 7 and 10) could also have been used.

Having read the initial values, SNSIM now tests NTRIB. For a negative NTRIB the program ends. Usually NTRIB is the number of tributaries to be combined at a confluence and therefore SNSIM enters a do loop from 1 to NTRIB where the sum of the flow (SFLOW), and the COD, NOD, and DOD concentrations are computed by a mass balance. Then control will go to statement 9. At an upstream end of the system, NTRIB will be zero, and control will also go to statement 9. In either case at statement 9 the initial instream flow (FLOWI) is converted from cfs to cfd, and the total distance along a reach (TDIST) is initialized as zero or as the distance at which a previous reach terminated. SNSIM then enters a do loop from 1 to the number of sections in the reach (NSECT). The do loop begins by reading the section name (SNAME), section length (SLGTH), stream depth (DEPTH), stream velocity (VEL), waste or effluent flow at the head of the section (FLOWW), effluent COD (CODW), effluent NOD (NODW),

* A listing of the program is in Appendix A and a flow chart is on page 7.


START
READ REACH DATA
WRITE REACH DATA
NTRIB
AT THIS POINT MUST REACHES BE COMBINED DUE TO A CONFLUENCE?
NO
YES
SFLOW = ∑FLOWS FROM REACHES ENTERING CONFLUENCE
COD = ∑CBOD FROM REACHES ENTERING CONFLUENCE
NOD = ∑NBOD FROM REACHES ENTERING CONFLUENCE
DOD = ∑DO DEFICIT FROM REACHES ENTERING CONFLUENCE
I ≤ NSEC??
NO
YES
READ SECTION DATA
WRITE SECTION DATA
DIST = 0.0
① ALL CONVERSION FACTORS, TEMPERATURE CORRECTIONS AND PRELIMINARY CALCULATIONS ARE MADE
② ALL INPUTS TO THE UPSTREAM END OF THE SECTION (WASTE INPUTS, TRIBUTARY INPUTS, INPUTS FROM UPSTREAM SECTIONS OR REACHES) ARE COMBINED AND THE RESULTING INITIAL VALUES OF CBOD (COD), NBOD (NOD), DO DEFICIT (DOD) AND TOTAL STREAM FLOW (FLOW) FOR THE SECTION ARE CALCULATED BY A MASS BALANCE
SFLOW = 0.0
WRITE INITIAL VALUES FOR SECTION (COD, NOD, DOD, FLOW)
DIST = DIST + DELTA
CALL FOSS [RETURN WITH CBOD (CODC), NBOD (NODC), DOD (DODC) CONCENTRATIONS FOR X = DIST]
WRITE DIST, CODC, NODC, (SATURATION CONC OF O2 − DODC)
NO
HAVE CONCENTRATIONS BEEN CALCULATED TO THE DOWNSTREAM END OF THE SECTION?
YES
STORE DOWNSTREAM CONCENTRATIONS OF SECTION IN ORDER THAT THEY BE USED AS INPUT TO THE UPSTREAM END OF THE NEXT SECTION IN THE REACH
FLOW = FLOW, COD = CODC, NOD = NODC, DOD = DODC
STORE DOWNSTREAM CONCENTRATIONS OF PREVIOUS REACH SO THEY MAY BE USED WHEN COMBINING REACHES AT A CONFLUENCE. CODS (NRECH) = COD, NODS (NRECH) = NOD, DODS (NRECH) = DOD, FLOWS (NRECH) = FLOW

FLOW CHART FOR SNSIM

Figure 2

effluent D.O. Deficit (DODW), tributary flow at the head of the section (FLOWT), tributary COD (CODT), tributary NOD (NODT), tributary D.O. Deficit (DODT), water temperature (TEMP), carbonaceous BOD decay rate (KC), carbonaceous BOD deoxygenation rate (KD), nitrogenous BOD decay rate (KN), algae respiration (RESP), photosynthesis production (PHOTO), benthic oxygen demand (BENTH), and the carbonaceous (BANKC) and nitrogenous (BANKN) bank loads (agricultural and storm water runoff). The section distance is initialized as zero, and then the saturation constant[2] (CS) and the reaeration coefficient[3] (KR) are computed from:

$$C_s = 14.652 - 0.41022\ (TEMP) + 0.007991\ (TEMP)^2 - .000077774(TEMP)^3 \quad .....(4)$$

where

TEMP = Temperature in °C

$$KR = \frac{12.9\ (VEL)^{1/2}}{(DEPTH)^{3/2}} \quad .....(5)*$$

The stream velocity is then converted from ft/sec to ft/day. The tributary and effluent flows are converted from cfs to cfd. If the tributary flow is negative (water being taken out), then the COD, NOD, and DO deficit for the tributary are set equal to the instream COD, NOD, and DO deficit values.

As well, the following temperature correction factors are applied.

```
KC=KC*1.04**(T-20.)
KN=KN*1.04**(T-20.)
KD=KD*1.04**(T-20.)
BENTH = BENTH *1.08**(T-20.)
KR=KR*1.024**(T-20.)
```

All section input data is output in a clearly labelled form.

* The relationship was developed by O'Connor and Dobbins and was chosen for use as the most convenient and accurate functional relationship available for reaeration. It must be stressed that this relationship is but one of several which have been proposed by investigators. In particular the relationship may not be applicable to all streams. For instance, it was not designed for

fast, turbulent shallow streams. Therefore it is cautioned that users become familiar with the limitations of any such relationship before assuming that it applies to the stream which is to be modelled. An excellent report on the subject has just been published by EPA and should be consulted as a reference.[4]

In the event that the O'Connor-Dobbins formulation is deemed inadequate for a particular application a number of options are available to the user:

1) Change the functional relationship (Statements SNSIM085 & SNSIM091) taking care to insure that all variables are in the proper units.

2) Compute reaeration independently and input it to the program.

   One way to do this would be to:

   a) delete cards 085 & 091

   b) read the value of KR (@ 20°C) in the position normally taken by DEPTH

   c) in position of card 091 place the following card:

      KR=KR *1.024**(TEMP-20.)

   d) in position of card 085 place the following card:

      KR=DEPTH

   e) all computation would now be correct but on the output the value of depth would be that of the reaeration coefficient.

(Of course if the user can program he can modify SNSIM as he desires).

The CODW and the NODW are then converted from lb/day to mg/l by a conversion factor:

$$CODW(mg/l) = \frac{CODW(\#/day)}{FLOWW(cfd)} * 454000 mg/\# * 3.531 \times 10^{-2} ft.^3/l \quad \ldots\ldots(6)$$

$$CODW(mg/l) = \frac{CODW(\#/day)}{FLOWW(cfd)} * 16026.5 \; mgft^3/\#1 \quad \ldots\ldots(7)$$

$$NODW(mg/l) = \frac{NODW(\#/day)}{FLOWW(cfd)} * 16026.5 \; mgft^3/\#1 \quad \ldots\ldots(8)$$

The total flow for the section is computed as the sum of the instream (FLOWI), effluent (FLOWW), tributary (FLOWT), and stored flows (SFLOW). The initial COD, NOD, and DOD are computed by a mass balance, for example:

$$COD = \frac{(CODI)(FLOWI)+(CODW)(FLOWW)+(CODT)(FLOWT)+(COD)(SFLOW)}{FLOW} \quad \ldots\ldots(9)$$

The carbonaceous and nitrogenous bank loads are then converted to compatible units as follows:

$$BANKC(mg/l/day) = \frac{BANKC(\#/mile/day)*VEL(ft/day)}{FLOW(cfd)*28.32\ 1/ft^3} * \frac{454000\ mg/\#}{5280.ft/mile} \quad \ldots\ldots(10)$$

$$BANKN(mg/l/day) = \frac{BANKN*VEL*454000}{28.32 * FLOW*5280.} \quad \ldots\ldots(11)$$

and the benthal demand is:

$$BENTH(mg/l/day) = \frac{BENTH(\#/ft^2/day)*454000\ mg/\#}{28.32\ 1/ft^3*DEPTH(feet)} \quad \ldots\ldots(12)$$

For output purposes the flow (FLOWA) is converted to cfs including a correction factor for round-off errors.* The actual D.O. level is computed by subtracting the D.O. deficit from the saturation constant. A variable (DIS) is defined for output as equal to the total downstream distance (TDIST) + 0.005, a round-off correction.*

The section number (I), name (SNAME), distance (DIS), COD, NOD, DO level (C), total flow (FLOWA) and total deficit (DOD), are printed. The section (DIST) and total (TDIST) distances are then incremented by DELTA, and the section distance (DIST) is tested against the section length.

*This round-off correction is only for computers (e.g. IBM 1130) which truncate when outputting.

If the section distance is greater than or equal to the section length, the total distance is redefined. This could happen if the distance was greater than the section length, so the difference between these two is subtracted from TDIST. DIST is then set equal to the section length, and DISTN is defined from DIST as the section distance in feet. PROF is then called.

Subroutine PROF

The CALL and SUBROUTINE statements for PROF are:

```
CALL PROF (CODC, COD, KC, NODC, NOD, KN, DODC, KR, DOD, DISTN, VEL,
           PHOTO, BENTH, RESP, BANKN, BANKC, KD, A3, B3, C3, D3,
           E3, F3, G3, H3)

SUBROUTINE PROF (EL, ELO, DKC, EN, ENO, DKN, D, R, DO, X, U, P, B, RE, WN,
                 WL, DKD, A3, B3, C3, D3, E3, F3, G3, H3)
```

Equations (1), (2) and (3) are computed in PROF with (3) being computed by component and then added to get the total deficit, e.g. equation 3a would correspond to A3.* The components are computed separately to aid in verification.

Returning to SNSIM, the actual DO level is computed based on the calculated DO deficit and the saturation concentration, and all computed values are output in a clearly labeled form. The corresponding stream distance is computed and the stream distance covered by SNSIM is checked against the stream length. If these two variables are not equal, control returns to statement 1, and changes in DIST will be computed, along with a new COD, NOD, and D.O., until DIST = SLGTH. Then the total flow becomes the initial flow for the next section, and the same changes are also made for COD, NOD, and DOD. SNSIM continues until all sections in the reach have been read in.

The total flows, distance, and computed COD, NOD, and DOD at the end of the reach are stored by FLOWS, SDIST, CODS, NODS, and DODS, respectively. Initial data is now read in for the next reach, and the process continues until the system is completed.

RESTRICTIONS

1) SNSIM is limited to combining a maximum of 4 tributaries at one confluence. This limit may be expanded to 9 by changing the dimension statement for NT. For more than 9 tributaries at one confluence, a change must be made in the stored variables as well.

*NOTE: See equation 3 and the nomenclature section for a precise definition of the components.

2) The number of reaches that may be stored at one time is 10. This limit may be changed by expanding the dimensions of FLOWS, CODS, DODS, and NODS.

Additional Comments:

- When inputting an effluent waste source (CODW, NODW, DODW) the accompanying waste flow (FLOWW) must be input even when it is negligible.

- Some users have commented that the deficit components shown in the output may be misleading.

  The deficit components printed for a section are the components for that section alone and do not reflect the effect of upstream sections. At the end of a section the various components are combined in a mass balance with all other deficit sources at that point and input to the next section downstream as a boundary condition. Each individual component is set to zero and new components for the section are computed.

INPUT REQUIREMENTS AND DATA DESCRIPTION

Column	Variable	Description	Format
Card One:			
1-80	TITLE	River Name	20A4
Card Two:	"Reach Data"		
1-10	FLOWI	Instream Flow (CFS)	F10.0
11-20	CODI	Instream COD (mg/1)	F10.0
21-30	NODI	Instream NOD (mg/1)	F10.0
31-40	DODI	Instream D.O. Deficit (mg/1)	F10.0
41-50	DELTA	Section Increment Size (miles)	F10.0
51-55	NDIST	Reach number of starting milepoint	I5
56-60	NSECT	No. of Sections in Reach	I5
61-62	NRECH	Reach Number	I2
63-64	NTRIB	No. of Reaches to Combine	I2
65-72	NT(1-4)	Reach Numbers to be Combined	4I2
Card Three:	"Section Data"		
1-4	SNAME	Section Name	A4
9-16	SLGTH	Section Length (miles)	F8.0
17-24	DEPTH	Stream Depth (ft)	F8.0
25-32	VEL	Stream Velocity (f/s)	F8.0
33-40	FLOWW	Waste Flow (CFS)	F8.0
41-48	CODW	Effluent COD (#/day)	F8.0
49-56	NODW	Effluent NOD (#/day)	F8.0
57-64	DODW	Effluent D.O. Deficit (mg/1)	F8.0

Column	Variable	Description	Format
65-72	FLOWT	Minor tributary flow (cfs)	F8.0
Card Four:			
1-6	CODT	Concentration of CBOD in minor tributary (mg/l)	F6.0
7-12	NODT	Concentration of NBOD in minor tributary (mg/l)	F6.0
13-18	DODT	Concentration of D. O. deficit in minor tributary (mg/l)	F6.0
19-24	TEMP	Water temperature of section (°C)	F6.0
25-30	KC	CBOD removal rate (1/day)	F6.0
31-36	KD	Carbonaceous deoxygenation rate (1/day)	F6.0
37-42	KN	NBOD removal rate (1/day)	F6.0
43-48	RESP	Respiration rate of algae (mg/l/day)	F6.0
49-54	PHOTO	Photosynthetic rate of algae (mg/l/day)	F6.0
55-60	BENTH	Benthal oxygen demand (#/ft^2/day)	F6.0
61-66	BANKC	Uniform CBOD load (#/ft/day)	F6.0
67-72	BANKN	Uniform NBOD load (#/ft/day)	F6.0

Repeat cards 3 and 4 until NSECT sections have been included in the data deck. For a new reach begin with card 2.

NOMENCLATURE

VARIABLE NAME Program	VARIABLE NAME Other	DESCRIPTION	UNITS*
A3	Equation 3a	Deficit due to point source of DO deficit and initial value of DO deficit	M/L^3
B3	Equation 3b	Deficit due to point source or initial value of CBOD	M/L^3
BANKC & WL	$CBOD_d$	Distributed source of CBOD	M/L/T (as input) $M/L^3/T$ (as converted) **
BANKN & WN	$NBOD_d$	Distributed source of NBOD	M/L/T (as input) $M/L^3/T$ (as converted) **
BENTH & B	Sb	Benthal oxygen demand	$M/L^2/T$ (as input) $M/L^3/T$ (as converted)**
C3	Equation 3c	Deficit due to point source of NBOD	M/L^3
CODC & EL	CBOD	Carbonaceous biochemical oxygen demand	M/L^3
COD & ELO	$CBOD_o$	Point source of CBOD	M/L^3
CS	Cs	Saturation value of dissolved oxygen	M/L^3
CODW	CODW	Point source of CBOD due to a waste load	M/T
CODT	CODT	Point source of CBOD due to a minor tributary	M/L^3
CODI	CODI	Initial point source of CBOD at an upstream end of the system	M/L^3
D3	Equation 3d	Deficit due to distributed source of CBOD with no significant addition to river flow	M/L^3
D & DODC	D	Dissolved oxygen deficit	M/L^3
DEPTH	DEPTH	Depth of stream	L

*M: mass, L: length, T: time
** : see page 9

VARIABLE NAME Program	VARIABLE NAME Other	DESCRIPTION	UNITS*
DIST & DISTN X	X	Distance from an initial point at which calculations are to be made	L
DODW	DODW	Amount of deficit from a point waste source	M/L^3
DODT	DODT	Concentration of deficit in a point source minor tributary	M/L^3
DODI	DODI	Initial point source of deficit at the upstream nd of the system	M/L^3
DOD & DO	D_o	Point sources of deficit	M/L^3
E3	Equation 3e	Deficit due to distributed source of NBOD with no significant addition to river flow	M/L^3
FLOW	FLOW	Total flow	L^3/T
FLOWI	FLOWI	Initial flow at the head end of the system	L^3/T
FLOWT	FLOWT	Flow of a minor tributary	L^3/T
FLOWW	FLOWW	Flow of a waste source	L^3/T
F3	Equation 3f	Deficit due to distributed gross photosynthesis	M/L^3
G3	Equation 3g	Distributed algal respiration effect	M/L^3
H3	Equation 3h	Distributed benthal demand effect	M/L^3
KC & DKC	K_r	CBOD removal rate	1/T
KD & DKD	K_d	Deoxygenation rate (caused by CBOD)	1/T
KN & DKN	K_n	NBOD removal rate - deoxygenation rate (NBOD)	1/T
KR & R	K_a	Reaeration rate	1/T

VARIABLE NAME program	VARIABLE NAME other	DESCRIPTION	UNITS*
NODC & EN	NBOD	Nitrogenous Biochemical Oxygen Demand	M/L^3
NOD & ENO	$NBOD_o$	Point source of NBOD	M/L^3
NODW	NODW	Point source of NBOD due to waste load	M/T
NODT	NODT	Point source of NBOD from a minor tributary	M/L^3
NODI	NODI	Point source of NBOD from an initial source at the upstream end of the system	M/L^3
PHOTO & P	P	Algal photosynthetic rate	$M/L^3/T$
RESP & RE	R	Algal respiration rate	$M/L^3/T$
TEMP	TEMP	Temperature	°C
VEL	VEL	Velocity of stream	L/T

References

1. Thomann, R. V.: "Systems Analysis and Water Quality Management, "Environmental Research and Application, Inc., New York, 1971. pp 61-122

2. Solubility of Atmospheric Oxygen in Water, Twenty Ninth Progress Report of the Committee on San. Engr. Res. of San. Engr. Div., ASCE, Jour. San. Engr. Div., Vol. 86, No. SA4, July 1960 pp 41-53

3. O'Connor, D. J. and Dobbins, W.E. Mechanism of Reaeration in Natural Streams, Trans. Amer. Soc. Civil Engrs., Vol. 123, 1958 p 655

4. Tsivoglou, E. C. and Wallace, J. R. "Characterization of Stream Reaeration Capacity" prepared by Office of Research and Monitoring, USEPA, Washington, D. C., October 1972.

APPENDIX A

(listing of source deck)

The following listing of the source program was written in FORTRAN IV for use on the IBM 370/155 computer using a fortran G compiler.

To modify it so that it can be run on another computer (e.g. the IBM 1130) statements SNSIM051 and SNSIM052 which designate the input and output devices may have to be changed.

As well, if a computer is used which truncates it output * (as opposed to round-off which is employed by the IBM 370) the following changes should be made:

Make the following modifications:

```
   REAL NODI,NODW,NODT,NOD,NODC,KC,KN,KR,NODS(10),KD,NXD,NXDC          SNSIM006
   FLOWA=FLOW/86400.+0.005                                             SNSIM113
14 DIS=TDIST+0.005                                                     SNSIM134
```

Remove SNSIM120 and replace it with the following cards:

```
   CXD=COD+0.005
   NXD=NOD+0.005
   DXD=DOD+0.005
   S=C+0.005
   WRITE(NX,106)I,SNAME,DIS,CXD,NXD,S,FLOWA,DXD
```

Remove SNSIM135 and replace it with the following cards:

```
   S=C+0.005
   AX=A3+0.005
   BX=B3+0.005
   CX=C3+0.005
   DX=D3+0.005
   EX=E3+0.005
   GX=G3+0.005
   HX=H3+0.005
   CXDC=CODC+0.005
   NXDC=NODC+0.005
   DXDC=DODC+0.005
   WRITE(NX,105)DIS,CXDC,NXDC,S,AX,BX,CX,DX,EX,F3,GX,HX,DXDC
```

* e.g. IBM 1130

```
C*************************************************************************SNSIM000
C                                                                         *SNSIM001
C      PROGRAM SNSIM IS A ONE-DIMENSIONAL, STEADY-STATE, STRAIGHT-RUN     *SNSIM002
C      STREAM NETWORK SIMULATION MODEL.                                   *SNSIM003
C                                                                         *SNSIM004
C*************************************************************************SNSIM005
      REAL NODI,NODW,NODT,NOD,NODC,KC,KN,KR,NODS(10),KD                   SNSIM006
      DIMENSION TITLE(20),FLOWS(10),CODS(10),DODS(10),NT(4),SDIST(10)     SNSIM007
   33 FORMAT(/,' INPUT FOR SECTION ',A4,//,'    SLGTH =',F8.3,           SNSIM008
     1' MILES', 5X,'DEPTH=',F8.3,' FEET',10X,'VEL=',F8.3,1X,              SNSIM009
     2'FPS'/'   FLOWW=',F8.3,' CFS', 8X,'CODW=',F12.3,1X                  SNSIM010
     3'LBS/DAY', 4X,'NODW=',F12.3,' LBS/DAY', 4X,'DODW=',F8.3,1X,         SNSIM011
     4'MG/L'/'   FLOWT=',F8.3,' CFS', 8X,'CODT=',F8.3,' MG/L',11X,        SNSIM012
     1'NODT=',F8.3,' MG/L',11X,'DODT=',F8.3,' MG/L')                      SNSIM013
   34 FORMAT('   RESP=', F8.3,' MG/L/DAY     ', 'PHOTO=',F8.3,' MG/L/DAY'SNSIM014
     1,6X,'BANKC=',F8.3,' LBS/MI/DAY'                                     SNSIM015
     1,4X,'BANKN=',F8.3,' LBS/MI/DAY'//' ***************************** SNSIM016
     1*************************************************************      SNSIM017
     6**********************'          /'  REACTION RATES AS INPUT (TEMP =SNSIM018
     2 20 C)')                                                            SNSIM019
   35 FORMAT( '    KC=',F8.3,' /DAY',10X,                                SNSIM020
     3           'KD=',F8.3,' /DAY',13X,                                  SNSIM021
     3           'KN=',F8.3,' /DAY',13X,                                  SNSIM022
     3           'KR=',F8.5,' /DAY'/'   BENTH=',F7.4, 'LBS/FT**2/DAY')    SNSIM023
   36 FORMAT(/,'  REACTION RATES AS CONVERTED (TEMP = ',F5.1,' C)',/      SNSIM024
     4        '   KC=',F8.3,' /DAY',10X,                                  SNSIM025
     3           'KD=',F8.3,' /DAY',13X,                                  SNSIM026
     3           'KN=',F8.3,' /DAY',13X,                                  SNSIM027
     3           'KR=',F8.5,' /DAY'/'   BENTH=',F7.4, 'LBS/FT**2/DAY')    SNSIM028
   37 FORMAT(' ***********************************************************SNSIM029
     1*************************************************************'/)    SNSIM030
  100 FORMAT(20A4)                                                        SNSIM031
  101 FORMAT('1',26X,20A4//)                                              SNSIM032
  102 FORMAT(5F10.0,2I5,10I2)                                             SNSIM033
  103 FORMAT(A4,4X,8F8.0/12F6.0)                                          SNSIM034
  104 FORMAT(2X,'SECTION SECTION  DISTANCE     CBOD      NBOD      DO     FLSNSIM035
     1OW                  DEFICIT COMPONENTS                    TOTAL'    SNSIM036
     2/3X,'NUMBER   NAME  DOWNSTREAM',36X,'A3     B3     C3     D3     E3  SNSIM037
     2 F3     G3     H3   DEFICIT')                                        SNSIM038
  105 FORMAT(15X,F10.2,3X,3F8.2,8X,                                       SNSIM039
     28F6.2,F9.2)                                                         SNSIM040
  106 FORMAT(/,  I6,6X,A4, F9.2,3X,4F8.2,47X,F10.2)                       SNSIM041
  107 FORMAT(//,' INPUT FOR REACH ',I2,//,'   FLOWI =',F10.2,' CFS        SNSIM042
     1          CODI =',F10.2,' MG/L'/'   NODI =',F10.2,' MG/L           SNSIM043
     2,6X,'DODI =',F10.2,' MG/L'/'   DELTA =',F10.2,' MILES               SNSIM044
     3 NDIST =',I5,/,'   NSECT =',I5,25X,'NTRIB =',I2,/                   SNSIM045
     4'   NT(1)=',I2,'   NT(2)=',I2,'   NT(3)=',I2,'   NT(4)=',I2        SNSIM046
     5,//)                                                                SNSIM047
  902 FORMAT('1')                                                         SNSIM048
      DO 51 I=1,10                                                        SNSIM049
   51 SDIST(I)=0.0                                                        SNSIM050
      MX=5                                                                SNSIM051
```

```
      NX=6                                                                  SNSIM052
      SFLOW=0.0                                                             SNSIM053
      COD=0.0                                                               SNSIM054
      NOD=0.0                                                               SNSIM055
      DIS=0.                                                                SNSIM056
      DOD=0.0                                                               SNSIM057
      READ(MX,100)TITLE                                                     SNSIM058
      WRITE(NX,101)TITLE                                                    SNSIM059
   12 READ(MX,102)FLOWI,CODI,NODI,DODI,DELTA,NDIST,NSECT,NRECH,NTRIB,NT     SNSIM060
      IF(NSECT)28,11,28                                                     SNSIM061
   28 WRITE(NX,107)NRECH,FLOWI,CODI,NODI,DODI,DELTA,NDIST,NSECT,NTRIB,NTSNSIM062
      IF(NTRIB)11,9,8                                                       SNSIM063
    8 DO 10 I=1,NTRIB                                                       SNSIM064
      J=NT(I)                                                               SNSIM065
      SFLOW=SFLOW+FLOWS(J)                                                  SNSIM066
      COD=COD+FLOWS(J)*CODS(J)                                              SNSIM067
      NOD=NOD+FLOWS(J)*NODS(J)                                              SNSIM068
   10 DOD=DOD+FLOWS(J)*DODS(J)                                              SNSIM069
      COD=COD/SFLOW                                                         SNSIM070
      NOD=NOD/SFLOW                                                         SNSIM071
      DOD=DOD/SFLOW                                                         SNSIM072
    9 FLOWI=FLOWI*86400.                                                    SNSIM073
      IF(NDIST)11,16,15                                                     SNSIM074
   15 TDIST=SDIST(NDIST)                                                    SNSIM075
      GO TO 17                                                              SNSIM076
   16 TDIST=0.0                                                             SNSIM077
   17 DO 5 I=1,NSECT                                                        SNSIM078
      READ(MX,103)SNAME,SLGTH,DEPTH,VEL,FLOWW,CODW,NODW,DODW,FLOWT,         SNSIM079
     1CODT,NODT,DODT,TEMP,KC,KD,KN,RESP,PHOTO,BENTH,BANKC,BANKN             SNSIM080
      DIST=0.0                                                              SNSIM081
      WRITE(NX,33)SNAME,SLGTH,DEPTH,VEL,FLOWW,CODW,NODW,DODW,FLOWT,         SNSIM082
     1CODT,NODT,DODT                                                        SNSIM083
      WRITE(NX,34)RESP,PHOTO,BANKC,BANKN                                    SNSIM084
      KR=(12.9*VEL**0.5/DEPTH**1.5)                                         SNSIM085
      WRITE(NX,35)KC,KD,KN,KR,BENTH                                         SNSIM086
      KC=KC*1.04**(TEMP-20.)                                                SNSIM087
      KD=KD*1.04**(TEMP-20.)                                                SNSIM088
      KN=KN*1.04**(TEMP-20.)                                                SNSIM089
      BENTH=BENTH*1.08**(TEMP-20.)                                          SNSIM090
      CS=14.652-0.41022*TEMP+0.0079910*TEMP**2.-.000077774*TEMP**3.         SNSIM091
      KR=(12.9*VEL**0.5/DEPTH**1.5)*1.024 **(TEMP-20.)                      SNSIM092
      WRITE(NX,36)TEMP,KC,KD,KN,KR,BENTH                                    SNSIM093
      WRITE(NX,37)                                                          SNSIM094
      WRITE(NX,104)                                                         SNSIM095
      VEL=VEL*86400.                                                        SNSIM096
      FLOWT=FLOWT*86400.                                                    SNSIM097
      FLOWW=FLOWW*86400.                                                    SNSIM098
      IF(FLOWT)6,19,19                                                      SNSIM099
    6 CODT=CODI                                                             SNSIM100
      NODT=NODI                                                             SNSIM101
      DODT=DODI                                                             SNSIM102
   19 IF(FLOWW)7,18,7                                                       SNSIM103
```

```
 7 CODW=16026.5*CODW/FLOWW                                              SNSIM104
   NODW=16026.5*NODW/FLOWW                                              SNSIM105
18 FLOW=FLOWI+FLOWW+FLOWT+SFLOW                                         SNSIM106
   COD=(CODI*FLOWI+CODW*FLOWW+CODT*FLOWT+COD*SFLOW)/FLOW                SNSIM107
   NOD=(NODI*FLOWI+NODW*FLOWW+NODT*FLOWT+NOD*SFLOW)/FLOW                SNSIM108
   DOD=(DODI*FLOWI+DODW*FLOWW+DODT*FLOWT+DOD*SFLOW)/FLOW                SNSIM109
   BANKC=(454000.*BANKC*VEL)/(28.32*FLOW*5280.)                         SNSIM110
   BANKN=(454000.*BANKN*VEL)/(28.32*FLOW*5280.)                         SNSIM111
   BENTH=(454000.*BENTH)/(28.32*DEPTH)                                  SNSIM112
   FLOWA=FLOW/86400.                                                    SNSIM113
   SFLOW=0.0                                                            SNSIM114
   C=CS-DOD                                                             SNSIM115
   IF(C)23,24,24                                                        SNSIM116
23 C=0.0                                                                SNSIM117
   DOD=CS                                                               SNSIM118
24 DIS=TDIST                                                            SNSIM119
       WRITE(NX,106)I,SNAME,DIS,COD,NOD,C,FLOWA,DOD                     SNSIM120
   DIS=TDIST+DELTA                                                      SNSIM121
 1 DIST=DIST+DELTA                                                      SNSIM122
   TDIST=TDIST+DELTA                                                    SNSIM123
   IF(DIST-SLGTH)3,2,2                                                  SNSIM124
 2 TDIST=TDIST-(DIST-SLGTH)                                             SNSIM125
   DIST=SLGTH                                                           SNSIM126
 3 DISTN=DIST*5280.                                                     SNSIM127
   CALL PROF(CODC,COD,KC,NODC,NOD,KN,DODC,KR,DOD,DISTN,VEL,PHOTO,       SNSIM128
  1BENTH,RESP,BANKN,BANKC,KD,A3,B3,C3,D3,E3,F3,G3,H3)                   SNSIM129
   C=CS-DODC                                                            SNSIM130
   IF(C)13,14,14                                                        SNSIM131
13 C=0.0                                                                SNSIM132
   DOD=CS                                                               SNSIM133
14 DIS=TDIST                                                            SNSIM134
   WRITE(NX,105)DIS,CODC,NODC,C,A3,B3,C3,D3,E3,F3,G3,H3,DODC            SNSIM135
   IF(DIST-SLGTH)1,4,1                                                  SNSIM136
 4 FLOWI=FLOW                                                           SNSIM137
   CODI=CODC                                                            SNSIM138
   NODI=NODC                                                            SNSIM139
   DODI=DODC                                                            SNSIM140
 5 CONTINUE                                                             SNSIM141
   FLOWS(NRECH)=FLOWI                                                   SNSIM142
   CODS(NRECH)=CODI                                                     SNSIM143
   NODS(NRECH)=NODI                                                     SNSIM144
   DODS(NRECH)=DODI                                                     SNSIM145
   SDIST(NRECH)=TDIST                                                   SNSIM146
   WRITE(NX,902)                                                        SNSIM147
   GO TO 12                                                             SNSIM148
11 STOP                                                                 SNSIM149
   END                                                                  SNSIM150
```

```
 SUBROUTINE PROF(EL,ELO,DKC,EN,ENO,DKN,D,R,DO,X,U,P,B,RE,WN,WL,
1DKD,A3,B3,C3,D3,E3,F3,G3,H3)
 EN= (ENO*(EXP(-DKN*X/U)))+(WN/DKN)*(1-EXP(-DKN*X/U))
 EL= (ELO*(EXP(-DKC*X/U)))+(WL/DKC*(1-EXP(-DKC*X/U)))
 A3=  DO*  EXP(-R/U*X)
 B3=  (DKD/(R-DKC))*  (EXP(-  DKC/U*X)  -EXP(-R/U*X)) *ELO
 C3=  (DKN/(R-DKN))*  (EXP(-  DKN/U*X)  -EXP(-R/U*X)) *ENO
 D3=DKD/(R*DKC)*(1.-EXP(-R/U*X))*WL    -DKD/  ((R-DKC)*DKC)*(EXP(
1-DKC/U*X)  -EXP(-R/U*X))*WL
 E3=1. / R      *(1.-EXP(-R/U*X))*WN    -1. /   (R-DKN)*     (EXP(
1-DKN/U*X)  -EXP(-R/U*X))*WN
 F3=  -(1.-EXP(-R/U*X))*P/R
 G3=   (1.-EXP(-R/U*X))*RE/R
 H3=   (1.-EXP(-R/U*X))*B/R
 D=A3+B3+C3+D3+E3+F3+G3+H3
 RETURN
 END
```

PROF 000
PROF 001
PROF 002
PROF 003
PROF 004
PROF 005
PROF 006
PROF 007
PROF 008
PROF 009
PROF 010
PROF 011
PROF 012
PROF 013
PROF 014
PROF 015
PROF 016

APPENDIX B

(example problem)

The Anduin is a fictitious river system that can be modelled using SNSIM. As shown in figure B-1, it consists of a main stream which is fed by several tributaries. In figure B-2, a schematic of the system illustrates a segmentation scheme which could be used for this application. Each segment is given an acronym and each reach is given a number to identify it. For instance, reach 5 consists of segments LORI and MDAN. The physical, hydrologic and biological parameters which describe these sections are tabulated in Table B-1.

Various types of oxygen demanding loads are exerted along the Anduin System, including point waste loads from municipalities and industries, benthal loads due to sludge deposits, effects due to algal blooms in the lower reaches and initial background and runoff loadings due to agriculture in the headwaters. These loads are summarized in table B-2.

Finally, the data is punched onto computer cards as described on page 13 and as shown in figure B-3 and SNSIM is run. The resulting output is attached.

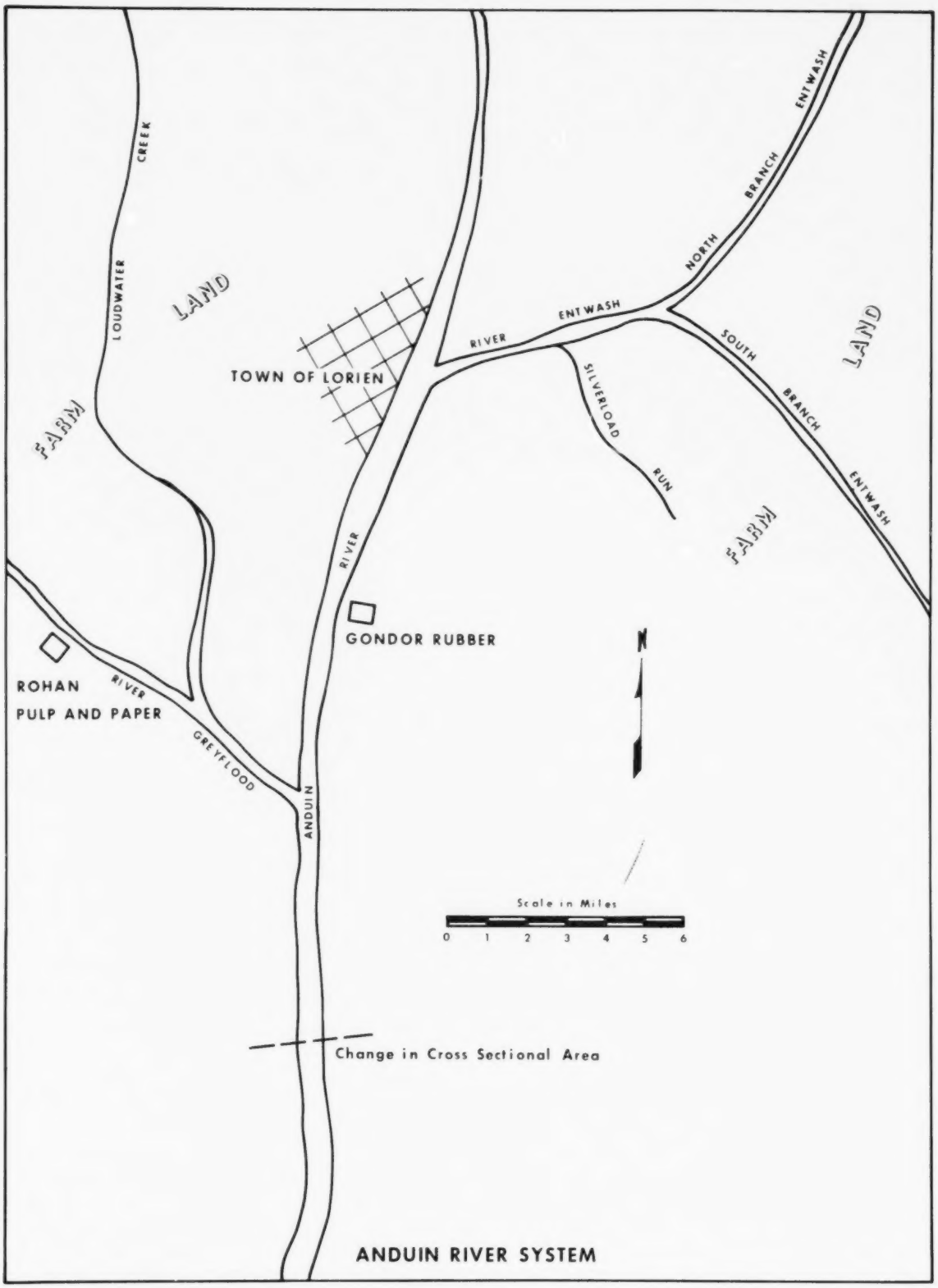

LOUDWATER CREEK
LAND
FARM
TOWN OF LORIEN
RIVER
ENTWASH
NORTH BRANCH ENTWASH
SOUTH BRANCH ENTWASH
LAND
SILVERLOAD RUN
FARM
RIVER
GONDOR RUBBER
ROHAN
PULP AND PAPER
RIVER
GREYFLOOD
ANDUIN
N
Scale in Miles
0 1 2 3 4 5 6
Change in Cross Sectional Area
ANDUIN RIVER SYSTEM

Figure B-1

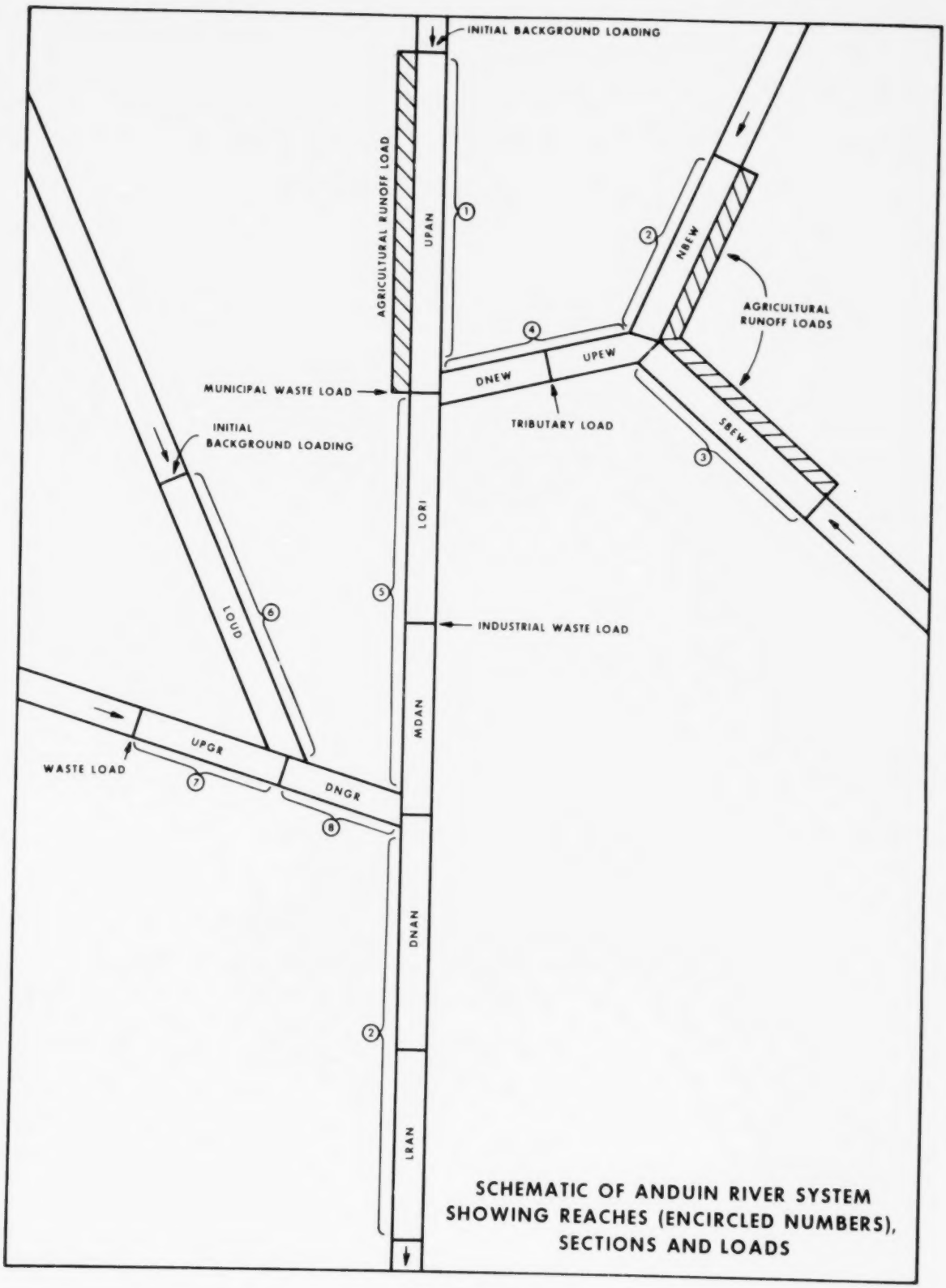

INITIAL BACKGROUND LOADING
AGRICULTURAL RUNOFF LOAD
UPAN
1
2
NBEW
AGRICULTURAL RUNOFF LOADS
4
UPEW
DNEW
MUNICIPAL WASTE LOAD
TRIBUTARY LOAD
SBEW
3
INITIAL BACKGROUND LOADING
LORI
5
LOUD
6
INDUSTRIAL WASTE LOAD
MDAN
UPGR
WASTE LOAD
7
DNGR
8
DNAN
2
LRAN
SCHEMATIC OF ANDUIN RIVER SYSTEM
SHOWING REACHES (ENCIRCLED NUMBERS),
SECTIONS AND LOADS

Figure B-2

REACH	SECTION	SLGTH (MILES)	DEPTH (FEET)	VEL (FPS)	TEMP °C	FLOWI (CFS)	FLOWT (CFS)	KC (1/DAY)	KD (1/DAY)	KN (1/DAY)
1	UPAN	9	10	.6	20	100		.3	.3	.1
2	NBEW	5	5	1.2	18	30		.3	.3	.1
3	SBEW	6	5	1.1	18	30		.3	.3	.1
4	UPEW	3	8	1.0	19			.3	.3	.1
	DNEW	3	8	1.0	19		2	.3	.3	.1
5	LORI	6	15	.5	20			.3	.2	.1
	MDAN	5	15	.5	21			.3	.3	.1
6	LOUD	8	1	1.0	18	10		.3	.3	.1
7	UPGR	4	8	.9	18	22		.3	.3	.1
8	DNGR	3	10	.8	19			.3	.3	.1
2	DNAN	6	20.	.4	20			.3	.3	.1
	LRAN	20	20.	.2	21			.3	.3	.1

TABLE B-1 SECTION PARAMETERS

REACH	SECTION	CODI	NODI	DODI	FLOWW	CODW	NODW	DODW	CODT	NODT	DODT	RESP	PHOTO	BENTH	BANKC	BANKN
1	UPAN	1.	1.	1.0											100.	100.
2	NBEW														100.	100.
3	SBEW														100.	100.
4	UPEW															
	NDEW								5.	5.	5.					
5	LORI				1.	5000.	5000.	7.						.0008		
	MDAN				1.	100.	0.	0.								
6	LOUD	2.	2.	.5												
7	UPGR				2.	1000.	0.	0.								
8	DNGR															
2	DNAN											.05	.5			
	LRAN											.1	1.			

TABLE B-2: SUMMARY OF LOADS*

*For units see input description

```
  MODEL OF ANDUIN RIVER SYSTEM
100.      1.          1.          1.          2.              1     1 1
UPAN     9.0      10.      .6
                    20. .3     .3     .1                              100.  100.
 30.                                                   2.                1 2
NBEW      5.0       5.      1.2
                    18. .3     .3     .1                              100.  100.
 30.                                                   2.                1 3
SBEW      6.0       5.      1.1
                    18. .3     .3     .1                              100.  100.
                                                       2.              2 4 2 2 3
UPEW      3.0       8.      1.0
                    19. .3     .3     .1
DNEW      3.0       8.      1.0                                                2.
5.     5.     5.          19. .3     .3     .1
                                                       2.              1     2 5 2 1 4
LORI      6.0      15.       .5        1.              5000.    5000.  7.
                    20. .3     .2     .1                          .0008
MDAN      5.0      15.       .5          1.            100.0
                    21. .3     .3     .1
 10.       2.          2.          .5                 2.                    1 6
LOUD      8.0       1.      1.0
                    18. .3     .3     .1
 22.                                                   2.                    1 7
UPGR      4.0       8.       .9        2.             1000.
                    18. .3     .3     .1
                                                       2.              7     1 8 2 7 6
DNGR      3.0      10.       .8
                    19. .3     .3     .1
                                                       2.              5     2 2 2 5 8
DNAN      6.0      20.       .4
                    20. .3     .3     .1     .05      .5
LRAN     20.0      20.       .2
                    21. .3     .3     .1     .1       1.
```

FIGURE B-3: INPUT DECK FOR EXAMPLE PROBLEM

MODEL OF ANDUIN RIVER SYSTEM

INPUT FOR REACH 1

FLOWI = 100.00 CFS CODI = 1.00 MG/L
NODI = 1.00 MG/L DODI = 1.00 MG/L
DELTA = 2.00 MILES NDIST = 1
NSECT = 1 NTRIB = 0
NT(1)= 0 NT(2)= 0 NT(3)= 0 NT(4)= 0

INPUT FOR SECTION UPAN

SLGTH = 9.000 MILES DEPTH= 10.000 FEET VEL= 0.600 FPS
FLOWW= 0.0 CFS CODW= 0.0 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 0.0 CFS CODT= 0.0 MG/L NODT= 0.0 MG/L DODT= 0.0 MG/L
RESP= 0.0 MG/L/DAY PHOTO= 0.0 MG/L/DAY BANKC= 100.000 LBS/MI/DAY BANKN= 100.000 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.31598 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 20.0 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.31598 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
1	UPAN	0.0	1.00	1.00	8.02	100.00									1.00
		2.00	1.30	1.35	7.99		0.94	0.06	0.02	0.01	0.00	0.0	0.0	0.0	1.03
		4.00	1.58	1.69	7.94		0.88	0.11	0.04	0.04	0.01	0.0	0.0	0.0	1.08
		6.00	1.85	2.02	7.87		0.82	0.15	0.05	0.09	0.03	0.0	0.0	0.0	1.15
		8.00	2.10	2.35	7.78		0.77	0.19	0.07	0.15	0.05	0.0	0.0	0.0	1.24
		9.00	2.22	2.51	7.73		0.75	0.21	0.08	0.19	0.07	0.0	0.0	0.0	1.29

INPUT FOR REACH 2

FLOWI = 30.00 CFS
NODI = 0.0 MG/L
DELTA = 2.00 MILES
NSECT = 1
NT(1)= 0 NT(2)= 0 NT(3)= 0 NT(4)= 0

CODI = 0.0 MG/L
DODI = 0.0 MG/L
NDIST = 0
NTRIB = 0

INPUT FOR SECTION NBEW

SLGTH = 5.000 MILES DEPTH= 5.000 FEET VEL= 1.200 FPS
FLOWW= 0.0 CFS CODW= 0.0 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 0.0 CFS CODT= 0.0 MG/L NODT= 0.0 MG/L DODT= 0.0 MG/L
RESP= 0.0 MG/L/DAY PHOTO= 0.0 MG/L/DAY BANKC= 100.000 LBS/MI/DAY BANKN= 100.000 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 1.26394 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 18.0 C)
KC= 0.277 /DAY KD= 0.277 /DAY KN= 0.092 /DAY KR= 1.20538 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
1	NBEW	0.0	0.0	0.0	9.40	30.00									
		2.00	1.22	1.23	9.38		0.0	0.0	0.0	0.02	0.01	0.0	0.0	0.0	0.0
		4.00	2.41	2.45	9.32		0.0	0.0	0.0	0.06	0.02	0.0	0.0	0.0	0.02
		5.00	2.99	3.06	9.27		0.0	0.0	0.0	0.10	0.03	0.0	0.0	0.0	0.08
															0.13

INPUT FOR REACH 3

FLOWI = 30.00 CFS CODI = 0.0 MG/L
NODI = 0.0 MG/L DODI = 0.0 MG/L
DELTA = 2.00 MILES NDIST = 0
NSECT = 1 NTRIB = 0
NT(1)= 0 NT(2)= 0 NT(3)= 0 NT(4)= 0

INPUT FOR SECTION SBEW

SLGTH = 6.000 MILES DEPTH= 5.000 FEET VEL= 1.100 FPS
FLOWW= 0.0 CFS CODW= 0.0 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 0.0 CFS CODT= 0.0 MG/L NODT= 0.0 MG/L DODT= 0.0 MG/L
RESP= 0.0 MG/L/DAY PHOTO= 0.0 MG/L/DAY BANKC= 100.000 LBS/MI/DAY BANKN= 100.000 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 1.21013 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 18.0 C)
KC= 0.277 /DAY KD= 0.277 /DAY KN= 0.092 /DAY KR= 1.15407 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
1	SBEW	0.0	0.0	0.0	9.40	30.00									0.0
		2.00	1.22	1.23	9.38		0.0	0.0	0.0	0.02	0.01	0.0	0.0	0.0	0.02
		4.00	2.40	2.45	9.31		0.0	0.0	0.0	0.07	0.02	0.0	0.0	0.0	0.09
		6.00	3.54	3.65	9.21		0.0	0.0	0.0	0.15	0.05	0.0	0.0	0.0	0.20

INPUT FOR REACH 4

FLOWI = 0.0 CFS CODI = 0.0 MG/L
NODI = 0.0 MG/L DODI = 0.0 MG/L
DELTA = 2.00 MILES NDIST = 0
NSECT = 2 NTRIB = 2
NT(1)= 2 NT(2)= 3 NT(3)= 0 NT(4)= 0

INPUT FOR SECTION UPEW

SLGTH = 3.000 MILES DEPTH= 8.000 FEET VEL= 1.000 FPS
FLOWW= 0.0 CFS CODW= 0.0 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 0.0 CFS CODT= 0.0 MG/L NODT= 0.0 MG/L DODT= 0.0 MG/L
RESP= 0.0 MG/L/DAY PHOTO= 0.0 MG/L/DAY BANKC= 0.0 LBS/MI/DAY BANKN= 0.0 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.57011 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 19.0 C)
KC= 0.288 /DAY KD= 0.288 /DAY KN= 0.096 /DAY KR= 0.55674 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
1	UPEW	0.0	3.27	3.36	9.05	60.00									0.16
		2.00	3.15	3.32	8.91		0.15	0.11	0.04	0.0	0.0	0.0	0.0	0.0	0.30
		3.00	3.10	3.30	8.85		0.15	0.16	0.06	0.0	0.0	0.0	0.0	0.0	0.36

INPUT FOR SECTION DNEW

SLGTH = 3.000 MILES DEPTH= 8.000 FEET VEL= 1.000 FPS
FLOWW= 0.0 CFS CODW= 0.0 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 2.000 CFS CODT= 5.000 MG/L NODT= 5.000 MG/L DODT= 5.000 MG/L
RESP= 0.0 MG/L/DAY PHOTO= 0.0 MG/L/DAY BANKC= 0.0 LBS/MI/DAY BANKN= 0.0 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.57011 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 19.0 C)
KC= 0.288 /DAY KD= 0.288 /DAY KN= 0.096 /DAY KR= 0.55674 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
2	DNEW	3.00	3.16	3.35	8.70	62.00									0.51
		5.00	3.05	3.31	8.59		0.48	0.11	0.04	0.0	0.0	0.0	0.0	0.0	0.62
		6.00	3.00	3.29	8.54		0.15	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.67

INPUT FOR REACH 5

FLOWI = 0.0 CFS
NODI = 0.0 MG/L
DELTA = 2.00 MILES
NSECT = 2
NT(1)= 1 NT(2)= 4 NT(3)= 0 NT(4)= 0

CODI = 0.0 MG/L
DODI = 0.0 MG/L
NDIST = 1
NTRIB = 2

INPUT FOR SECTION LORI

SLGTH = 6.000 MILES
FLOWW= 1.000 CFS
FLOWT= 0.0 CFS
RESP= 0.0 MG/L/DAY

DEPTH= 15.000 FEET
CODW= 5000.000 LBS/DAY
CODT= 0.0 MG/L
PHOTO= 0.0 MG/L/DAY

VEL= 0.500 FPS
NODW= 5000.000 LBS/DAY
NODT= 0.0 MG/L
BANKC= 0.0 LBS/MI/DAY

DODW= 7.000 MG/L
DODT= 0.0 MG/L
BANKN= 0.0 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.200 /DAY KN= 0.100 /DAY KR= 0.15701 /DAY
BENTH= 0.0008LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 20.0 C)
KC= 0.300 /DAY KD= 0.200 /DAY KN= 0.100 /DAY KR= 0.15701 /DAY
BENTH= 0.0008LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
1	LORI	9.00	8.19	8.48	7.93	163.00									
		11.00	7.61	8.28	7.19		1.05	0.38	0.20	0.0	0.0	0.0	0.0	0.21	1.09
		13.00	7.07	8.08	6.50		1.01	0.72	0.39	0.0	0.0	0.0	0.0	0.40	1.83
		15.00	6.57	7.88	5.88		0.97	1.02	0.57	0.0	0.0	0.0	0.0	0.59	2.52
															3.15

INPUT FOR SECTION MDAN

SLGTH = 5.000 MILES
FLOWW= 1.000 CFS
FLOWT= 0.0 CFS
RESP= 0.0 MG/L/DAY

DEPTH= 15.000 FEET
CODW= 100.000 LBS/DAY
CODT= 0.0 MG/L
PHOTO= 0.0 MG/L/DAY

VEL= 0.500 FPS
NODW= 0.0 LBS/DAY
NODT= 0.0 MG/L
BANKC= 0.0 LBS/MI/DAY

DODW= 0.0 MG/L
DODT= 0.0 MG/L
BANKN= 0.0 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.15701 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 21.0 C)
KC= 0.312 /DAY KD= 0.312 /DAY KN= 0.104 /DAY KR= 0.16078 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
2	MDAN	15.00	6.65	7.83	5.71	164.00									
		17.00	6.16	7.64	5.16		3.01	0.48	0.19	0.0	0.0	0.0	0.0	0.0	3.13
		19.00	5.71	7.45	4.67		2.68	0.90	0.37	0.0	0.0	0.0	0.0	0.0	3.68
															4.17

20.00	5.49	7.35	4.45	2.83	1.10	0.46	0.0	0.0	0.0	0.0	0.0	4.39

INPUT FOR REACH 6

FLOWI = 10.00 CFS CODI = 2.00 MG/L
NODI = 2.00 MG/L DODI = 0.50 MG/L
DELTA = 2.00 MILES NDIST = 0
NSECT = 1 NTRIB = 0
NT(1)= 0 NT(2)= 0 NT(3)= 0 NT(4)= 0

INPUT FOR SECTION LOUD

SLGTH = 8.000 MILES DEPTH= 1.000 FEET VEL= 1.000 FPS
FLOWW= 0.0 CFS CODW= 0.0 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 0.0 CFS CODT= 0.0 MG/L NODT= 0.0 MG/L DODT= 0.0 MG/L
RESP= 0.0 MG/L/DAY PHOTO= 0.0 MG/L/DAY BANKC= 0.0 LBS/MI/DAY BANKN= 0.0 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR=12.90000 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 18.0 C)
KC= 0.277 /DAY KD= 0.277 /DAY KN= 0.092 /DAY KR=12.30242 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
1	LOUD	0.0	2.00	2.00	8.90	10.00									0.50
		2.00	1.93	1.98	9.25		0.11	0.03	0.01	0.0	0.0	0.0	0.0	0.0	0.16
		4.00	1.87	1.96	9.32		0.02	0.04	0.01	0.0	0.0	0.0	0.0	0.0	0.08
		6.00	1.81	1.93	9.34		0.01	0.04	0.01	0.0	0.0	0.0	0.0	0.0	0.06
		8.00	1.75	1.91	9.35		0.00	0.04	0.01	0.0	0.0	0.0	0.0	0.0	0.06

INPUT FOR REACH 7

FLOWI = 22.00 CFS CODI = 0.0 MG/L
NODI = 0.0 MG/L DODI = 0.0 MG/L
DELTA = 2.00 MILES NDIST = 0
NSECT = 1 NTRIB = 0
NT(1)= 0 NT(2)= 0 NT(3)= 0 NT(4)= 0

INPUT FOR SECTION UPGR

SLGTH = 4.000 MILES DEPTH= 8.000 FEET VEL= 0.900 FPS
FLOWW= 2.000 CFS CODW= 1000.000 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 0.0 CFS CODT= 0.0 MG/L NODT= 0.0 MG/L DODT= 0.0 MG/L
RESP= 0.0 MG/L/DAY PHOTO= 0.0 MG/L/DAY BANKC= 0.0 LBS/MI/DAY BANKN= 0.0 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.54085 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 18.0 C)
KC= 0.277 /DAY KD= 0.277 /DAY KN= 0.092 /DAY KR= 0.51579 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
1	UPGR	0.0	7.73	0.0	9.40	24.00									0.0
		2.00	7.44	0.0	9.13		0.0	0.28	0.0	0.0	0.0	0.0	0.0	0.0	0.28
		4.00	7.17	0.0	8.88		0.0	0.52	0.0	0.0	0.0	0.0	0.0	0.0	0.52

INPUT FOR REACH 8

FLOWI = 0.0 CFS CODI = 0.0 MG/L
NODI = 0.0 MG/L DODI = 0.0 MG/L
DELTA = 2.00 MILES NDIST = 7
NSECT = 1 NTRIB = 2
NT(1)= 7 NT(2)= 6 NT(3)= 0 NT(4)= 0

INPUT FOR SECTION DNGR

SLGTH = 3.000 MILES DEPTH= 10.000 FEET VEL= 0.800 FPS
FLOWW= 0.0 CFS CODW= 0.0 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 0.0 CFS CODT= 0.0 MG/L NODT= 0.0 MG/L DODT= 0.0 MG/L
RESP= 0.0 MG/L/DAY PHOTO= 0.0 MG/L/DAY BANKC= 0.0 LBS/MI/DAY BANKN= 0.0 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.36487 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 19.0 C)
KC= 0.288 /DAY KD= 0.288 /DAY KN= 0.096 /DAY KR= 0.35632 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
1	DNGR	4.00	5.57	0.56	8.82	34.00									0.39
		6.00	5.33	0.55	8.60		0.37	0.23	0.01	0.0	0.0	0.0	0.0	0.0	0.61
		7.00	5.22	0.55	8.50		0.36	0.34	0.01	0.0	0.0	0.0	0.0	0.0	0.71

INPUT FOR REACH 2

FLOWI = 0.0 CFS CODI = 0.0 MG/L
NODI = 0.0 MG/L DODI = 0.0 MG/L
DELTA = 2.00 MILES NDIST = 5
NSECT = 2 NTRIB = 2
NT(1)= 5 NT(2)= 8 NT(3)= 0 NT(4)= 0

INPUT FOR SECTION DNAN

SLGTH = 6.000 MILES DEPTH= 20.000 FEET VEL= 0.400 FPS
FLOWW= 0.0 CFS CODW= 0.0 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 0.0 CFS CODT= 0.0 MG/L NODT= 0.0 MG/L DODT= 0.0 MG/L
RESP= 0.050 MG/L/DAY PHOTO= 0.500 MG/L/DAY BANKC= 0.0 LBS/MI/DAY BANKN= 0.0 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.09122 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 20.0 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.09122 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
1	DNAN	20.00	5.45	6.18	5.26	198.00									3.76
		22.00	4.97	6.00	4.85		3.66	0.47	0.18	0.0	0.0	-0.15	0.02	0.0	4.17
		24.00	4.53	5.82	4.49		3.55	0.89	0.36	0.0	0.0	-0.30	0.03	0.0	4.53
		26.00	4.14	5.64	4.19		3.46	1.25	0.52	0.0	0.0	-0.44	0.04	0.0	4.83

INPUT FOR SECTION LRAN

SLGTH = 20.000 MILES DEPTH= 20.000 FEET VEL= 0.200 FPS
FLOWW= 0.0 CFS CODW= 0.0 LBS/DAY NODW= 0.0 LBS/DAY DODW= 0.0 MG/L
FLOWT= 0.0 CFS CODT= 0.0 MG/L NODT= 0.0 MG/L DODT= 0.0 MG/L
RESP= 0.100 MG/L/DAY PHOTO= 1.000 MG/L/DAY BANKC= 0.0 LBS/MI/DAY BANKN= 0.0 LBS/MI/DAY

****

REACTION RATES AS INPUT (TEMP = 20 C)
KC= 0.300 /DAY KD= 0.300 /DAY KN= 0.100 /DAY KR= 0.06450 /DAY
BENTH= 0.0 LBS/FT**2/DAY

REACTION RATES AS CONVERTED (TEMP = 21.0 C)
KC= 0.312 /DAY KD= 0.312 /DAY KN= 0.104 /DAY KR= 0.06605 /DAY
BENTH= 0.0 LBS/FT**2/DAY

****

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	G3	H3	TOTAL DEFICIT
2	LRAN	26.00	4.14	5.64	4.01	198.00									4.83
		28.00	3.42	5.29	3.69		4.64	0.70	0.34	0.0	0.0	-0.60	0.06	0.0	5.15
		30.00	2.82	4.97	3.54		4.46	1.26	0.65	0.0	0.0	-1.17	0.12	0.0	5.31

32.00	2.33	4.66	3.50	4.28	1.69	0.92	0.0	0.0	-1.73	0.17	0.0	5.34
34.00	1.93	4.38	3.58	4.11	2.02	1.17	0.0	0.0	-2.26	0.23	0.0	5.26
36.00	1.59	4.11	3.73	3.95	2.27	1.38	0.0	0.0	-2.77	0.28	0.0	5.11
38.00	1.32	3.85	3.95	3.79	2.45	1.58	0.0	0.0	-3.26	0.33	0.0	4.89
40.00	1.09	3.62	4.23	3.64	2.57	1.75	0.0	0.0	-3.73	0.37	0.0	4.61
42.00	0.90	3.39	4.55	3.50	2.66	1.90	0.0	0.0	-4.18	0.42	0.0	4.29
44.00	0.74	3.18	4.90	3.36	2.71	2.03	0.0	0.0	-4.61	0.46	0.0	3.94
46.00	0.61	2.99	5.28	3.23	2.72	2.14	0.0	0.0	-5.03	0.50	0.0	3.57

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Robert E. Braster
Steven C. Chapra